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Critical Climate-Sensitive and Important Grain-Producing Regions: Grain Production/Yield Variations Due to Climate Fluctuations

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Abstract

Ideally, the Crop Country Inventory, CCI, is a methodology for the pre-harvest prediction of large variations in a country's crop production. This is accomplished by monitoring the historical climatic fluctuations, especially during the crop calendar period, in a climate sensitive large crop production region or sub-country, rather than the entire country. The argument can be made that the climatic fluctuations in the climatic sensitive region are responsible for the major annual crop country variations and that the remainder of the country, without major climatic fluctuations for a given year, can be assumed to be a steady-state crop producer. The principal data set that has been used is the Global Climate Mode (GCM) data from the National Center for Environmental Prediction (NCEP), taken over the last half century. As a test of its accuracy, GCM data can and has been correlated with the actual meteorological station data at the station site.

Pre-harvest crop production variations can be predicted for climate-sensitive regions by correlating and modeling the crop production variations to historically known cyclic and repeated types of climatic fluctuations over a period of decades. As a classic example, the Former Soviet Union (FSU) has historically known cyclic and repeated types of climatic variations that include winter-kill for the winter wheat crop in western FSU and drought for the spring wheat crop in Central Asia. Ideally, the selected crop producing region's output represents a large portion of the selected country's output, say 25 to 35 percent or more.

This CCI strategic economic intelligence methodology is a socio-economic approach for monitoring individual crop countries for a variety of justifications, and has global applicability for all countries with reporting statistics. If the country of interest has a small agricultural region with a small crop output, the correlation of crop production variation with climatic fluctuations can be done on a country-wide basis. Both pre-harvest and post-harvest analyses have value for a variety of applications. This CCI methodology for individual countries is a distinctly different approach from visual satellite monitoring of global ecological changes in the extent of forests, glaciers, snow cover, and other visual effects that can span continents or multi-country areas.

A major justification for the full development of the CCI methodology using the latest GCM database was the failure of the costly multi-million dollar 1970s Large Area Crop Inventory Experiment (LACIE) Project. This Project, a NASA, NOAA, and USDA consortium effort that employed LANDSAT as a crop monitor, attempted to predict large wheat crop production variations in the Former Soviet Union (FSU) by statistically sampling the entire country. LACIE was an effort that lasted over a 5-year period, produced a massive and still viable cost-benefit study, and had been initiated to predict pre-harvest unreported wheat crop failures in the FSU that had caused under evaluation of wheat crop pricing and had resulted in major U.S. export losses.

Introduction

Over centuries, the world's food supply has barely stayed ahead of the demands from a growing global population. Even so, without the proper distribution of globally available food supplies to regions without the capability to supply their own demands, great starvation and death has occurred over and over again throughout the centuries of historical record. Currently, even with the most modern and technically advanced agricultural practices, climate still has the potential to cause great havoc with food production and supply throughout the world. A Crop Country Inventory (CCI) study is focused to identify and analyze vulnerable agricultural regions with repetitive and identified fluctuating climatic conditions and predict the resultant large and frequent annual variations in production.

This is a new way to analyze and predict the effects of climate on the most vulnerable regions of CCI for a particular country. If the country is a major global source of a particular staple crop, its predicted shortfall provides an early warning of the subsequent effects on the global food supply for any specific year. It allows early predictions of shortfalls from historical analyses of climate fluctuations and their cyclic nature for climate-sensitive regions with historically large variations in crop production. In addition, it is a new and valuable approach to retrospective analyses of the utilization of large loans to improve agricultural production for country systems over a multi-year period, such as those required by an organization such as the World Bank, as an example. Simply, the results of the borrowing country's efforts to improve agricultural production can only be properly evaluated when the effects of unusually good or bad climatic conditions have been separated from the efforts to improve production under normal climatic conditions.

This paper introduces the concept of a CCI, a methodology for the pre-harvest prediction of large scale climate sensitive crop production variations for a large and important crop producing sub-country or region within an identified globally important crop producing country. The most extended predictive approach can be made only for a selected few ideal scenarios. These scenarios apply only to important climate sensitive crop production sub-countries or regions within identified globally important crop producing countries. However, the methodology has general and global applicability for predicting and assessing crop production variations due to climatic fluctuations over different periods in the crop calendar for any country. If the country of interest has a small agricultural area with a small crop output, the correlation of crop production variation with climatic fluctuations can be done on a country-wide basis.

Regional crop production variations can be predicted by correlating and modeling these reported crop variations to known cyclic and repeated types of climate fluctuations, such as drought or grain winterkill. The methodology is most effective when the climatic fluctuations are historically cyclic over a period of decades. Recently processed Global Climate Model (GCM) data over the last 50 years is the principal climatic fluctuation data source. The accuracy of the GCM data can and has been tested by correlating it with meteorological station data at the station site.

Ideally, for maximum effectiveness in predicting country crop production variations from sub-country or regional climatic fluctuations, the selected crop producing region's output should represent a large portion of the selected country output. Regional crop production of 25 to 35% or more of the entire country crop production is a requirement to allow the monitoring of the climate sensitive region rather than the entire country.

A variety of applications exist for the use of CCI monitoring. For example, the methodology can be used to predict pre-harvest crop production variations for countries with poor or late reported agricultural statistics to predict the global crop availability for any year and the subsequent price variation for global exports and imports. The same methodology can also be used in post-harvest crop production to assess the effects of climatic fluctuations alone on crop production for developing agricultural systems. If the developing agricultural systems have been funded for improvement, as is done for a loan from the World Bank, a measure of the actual crop production improvement can be made after separating out the effects of climate fluctuations.

The most extended CCI approach is an ideal scenario that can be applied to a large and important crop producing region within an identified globally important stable crop producing country. Prediction of crop production variations for types of wheat crop for the Former Soviet Union (FSU) is a prime example.

A major justification for the full development of the CCI methodology using the latest GCM data base was the failure of the costly multi-million dollar project in the 1970s, the Large Area Crop Inventory Experiment, LACIE. This project, a NASA, NOAA and USDA consortium effort using LANDSAT, was undertaken to predict large wheat crop production variations in the FSU. The LACIE project was a large scale effort by hundreds of researchers that lasted over a 5-year period. It produced a massive and still viable cost-benefit study and had been initiated to predict pre-harvest wheat crop failures in the FSU that had resulted in major U.S. export losses in the early 1970s.

General Methodology

Figure 1, in the appendix, is a general schematic methodology for the Input/Output Crop Country Flow. It outlines the Inputs and Outputs of the CCI approach to assessing the crop output for an identified country for a specific year. The first justification for such a study is the prioritization, listed in the upper left-hand column. If a large crop-producing county has a disastrous crop production shortfall harvest of an important crop, such as wheat, the price of the crop on the world market can show a great increase in price. Any other country producing and selling the same crop on the world market without knowledge of a disastrous wheat production short-fall could lose millions of dollars from the sale. This actually did occur in 1972 when the FSU had an unanticipated short-fall in wheat production and the United States exported large amounts of wheat at a normal price, unaware of the anticipated production short-fall in the FSU. As a result of the export losses, the $60 million dollar LACIE Project was undertaken by a consortium of three U.S. Government Agencies, NASA, NOAA, and the USDA. The data source was LANDSAT data that was unequal to the task. The LACIE Project with its $2 million dollar cost-benefit studies in the 1970s, although unsuccessful, certainly serves as a justification for the current CCI Project using a new, state-of-the-art data source. The LACIE Project will be more fully discussed later in this paper.

In the Appendix, Figure 1, a schematic of the INPUT/OUTPUT CROP COUNTY INVENTORY FLOW is shown. In this schematic, the principal justification for the Flow Diagram, Prioritization, is shown in the upper left-hand corner. Although there are a number of possible prioritizations, the one listed here is "Economic Impact on the United States (Export $) Effective," a justification elucidated in the Cost Benefit Studies completed for the LACIE Project.

In the lower left hand column of Figure 1, and continued over into the lower right hand column of Figure 1, are the climate sensitive regional or sub-countries of the major crop county that is being inventoried. The monitoring of these climate sensitive regions can indicate an annual major crop failure for the entire country, without having to monitor the entire country. The historic variability of the regional climate fluctuations have been the major and highly variable factors producing the greatest losses for almost every known example. In comparison to the rapidly changing climate sensitive factors, almost all other agricultural factors can be considered slowly moving steady state variables changing crop production only a few percent over periods of years.

The principal physical observables are the climate fluctuations for the CCIs for the critical periods over the specific crop calendar growth periods. Other observables can include spatial, spectral, and temporal indicators taken from the ground or a space platform. All appropriate observables can then be fed into correlation models to provide improved information for predicting crop variability or failures. The size of crop variability for an individual crop can then be translated into related economic benefits from the improved prediction from the crop county statistics shown in the upper far right hand column of Figure 1.

Figures 2 and 3, In the Appendix, constitute a framework outline of potential CCI Analyses for Globally Significant Producing Crop Countries for the 1971-72 period, the approximate mid-point of the proposed 50 year CCI period of observation and monitoring. In Figure 2, the magnitudes of the global crop production in millions of metric tons, MMT, for 12 different crops have been listed and the Principal Producing Crop Countries are ordered below the global crop production by the magnitude of their production. The first eight crops listed are grains, followed by the crops of potatoes, sugar beets, soybeans, sunflower seeds, and cotton. From the listings in Figure 2, the FSU lead the world in the production of the grain crops of wheat, barley, oats, and rye. In addition, the FSU also led the world in the production of potatoes, sugar beets, sunflower seeds, and cotton.

There is significance in the FSU's leading world production for some crops. For example, although the FSU leads the world in wheat production, it uses some of its wheat production for carbohydrates in fodder for its livestock production, whereas the United States, the world's leading producer of corn, uses corn for fodder in its livestock production. The FSU, under Krushchev, attempted a massive corn production program in its New Lands Program in Central Asia in 1954, but it was a failure because of insufficient moisture. Again, although the FSU is the leading producer of sunflower seeds in the world, they are used for their protein content in livestock feed, while the U.S., the world's leading producer of soybeans, uses soy for protein for its enormous livestock production.

In Figure 3, the same crops listed in Figure 2, with the addition of buckwheat and flax fiber, have been represented in pie charts showing the relative percentage production contribution of the major crop producer countries for each of the eight grains and the other six designated crops. In the bottom panel of Figure 3, the production per capita is listed for the crops of wheat rice, barley, and corn. Also shown is the distribution of the world's population among four specific countries and other collections of countries.

From Figure 3, the FSU produced in excess of 25% of the world wheat production on average in the 1971-72 period, compared to the approximate 15% wheat production of the U.S.. For barley, the FSU produced slightly less than 25% of the world's production, while the U.S. ranked fifth in production. For oats, the FSU a little more than 25% of the world's production, while the U.S. ranked second with a little less than 25%. The FSU's percentage of global rye production is in the vicinity of 40% and potato production is in the vicinity of 30%, with the US's small share of production ranked fifth in the world for both crops. The FSU produces 80-90% of the global buckwheat production, more than 50% of the world's sunflower seeds, approximately 40% of the world's flax fiber production, and approximately 30% of the world's sugar beets. The only crop that the U.S. and the FSU are approximately equal producers is the cotton crop. The People's Republic of China (PRC) produces approximately 40% of the world's rice production and more than 50% of the millet crop. The U.S. is the world's greatest producer of corn, nearly 50% of the total global production and soybeans, nearly 40% of the total global production. These two crops are the major resources of carbohydrates and protein for U.S. livestock production.

In Figure 4 (in the Appendix), a representation has been made to depict the CCI analysis approach. The objective of the analysis is to predict any large variation in crop production of designated crop countries, during any period in the crop calendar, preferably as early as possible. This objective requires the monitoring of historically large and periodic climatic fluctuations of any size crop country or the monitoring of the history of large and periodic climate fluctuations in climate-sensitive regions producing a large fraction of production of a globally large and important crop producing country, the focus of the CCI. The technique of monitoring a climate sensitive region or sub-country of a large and important crop producing country rather than the entire country is restricted to a selective small number of cases satisfying a set of critical criteria.

The climatic data necessary to monitor a crop country are designated as physical observables that may or may not be derived from satellite monitoring. For the projected CCI monitoring, the GCM is the primary source of data. If any data can be employed from satellite monitoring, this could lead to appropriate additional satellite design specifications or requirements.

An initial listing or justification for the CCI monitoring could certainly include a perceived and informed pricing for U.S. exports for realistic profits considering the global availability of a particular crop. The normal input-output equation of crop production and its use, has been shown on the right side of Figure 4, as

$$\text{Production} + \text{Imports} = \text{Exports} + \text{Utilization} + \text{Storage}$$

$$\text{Utilization} = \text{Food} + \text{Feed} + \text{Seed} + \text{Industrial Uses} + \text{Storage}$$

Two specific CCI regions or sub-country examples for the previously specified enormous crop production output of the FSU are the winter wheat production of the Ukraine and the spring wheat production of Kazakhstan. The specific spring wheat example for Kazakhstan will be detailed in a future paper.

In Figure 5, in the Appendix, a Spatial-Spectral-Temporal Resolution of the CCI approach has been shown. The primary Crop Country examples that have been shown are the FSU for its wheat crop and the PRC for its rice crop. The United States is listed as a secondary producer of wheat but its statistics are readily open and available, unlike the statistics for the FSU.

The spatial analyses of a particular Crop Country or even a climate sensitive sub-country or region can be elevated to higher resolution by considering smaller and smaller sub-regions, provided there are published agricultural statistics for the smaller regions. For the proposed example of spring wheat growth in Kazakhstan in Central Asia, analyses can be taken down to the oblast or krai level, where statistics exist. The oblast or krai level are roughly equivalent to county level statistics in the United States. Depending on the period considered, there have been roughly more than ten and less than twenty oblasts in Kazakhstan in recent years.

Temporal factors include climatic conditions that occur prior to planting, such as events producing moisture in the soil. Other sensitive temporal factors occur between the planting, stages of growth, and finally the harvesting and post-harvest conditions of the crop. For spring wheat production in the FSU, the spring wheat production in Central Asia, especially in Kazakhstan, is an essential element. The moisture in the April to August crop calendar is a critical element for good crop yield. This moisture level is subject to drought typically one to three times every decade. These drought conditions have been monitored over the 50 year test period with GCM data correlated with station data at the station location for some verification of the GCM data set.

The static factors affecting crop growth are listed, and the dynamic factors, especially climate factors, that would include drought conditions in Kazakhstan, are also listed. Spectral resolution could include spectral monitoring of crop color as an indicator of crop health and future yield, and such data can be included as an additional data source to augment the principal GCM data source.

General Applicability of the CCI

With the recognition of critical climate sensitive and important grain-producing regions, CCIs can be made by dividing globally significant agricultural country systems such as that of the FSU into steady-state and fluctuating components.[1] This initial production approach to important agricultural country systems has been incorporated into the foundation of larger study of the fluctuations of Central Asian climate and its effects on grain production. It employs a new modern composite digitized data set using a variety of climatic data sets, including GCM data, over a 50-year plus period. These GCM climatic data sets have been processed and prepared down to the sub-regional divisions or oblast level for the Central Asian Kazakhstan example. They are then correlated with reported agricultural statistics for a target country and then utilized in such a way as to model fluctuating climatic components with large variations in crop yields within agricultural country systems and within the digitized sub-regional boundaries. These oblast sub-divisions in the FSU and especially in Kazakhstan are roughly comparable to enormous sized counties in the United States. The modeled fluctuating climatic components can then be used to predict future crop yield performance or review past crop yield performance for a variety of resulting agricultural applications, including those for the World Bank. This modern composite digitized data set of a 50 year plus period incorporates a new flexible technique tested in Central Asia but with global applicability.

Analysis of Stable and Fluctuating Climate

This analysis of the separation of stable and slowly moving steady-state climatic fluctuations affecting agricultural production from the more rapid climatic fluctuations for identified sub-regions for a CCI, span the last 50-year period.[2] Normal meteorological data sets have been augmented with GCM data sets correlated with actual data at the latitude and longitude of the meteorological stations. A station and GCM climate data comparison already has been made for the Almati Oblast in Kazakhstan in Central Asia[3].

All other complexities outlined in this paper relating directly to the complicated national agricultural grain-producing system being considered, beside climate fluctuations, can be considered as more slowly developing steady-state factors, described as slowly changing multi-year trends in grain yield and production, for a constant planted region or area. Generally, for steady-state climatic conditions, all other factors together produce roughly a 5% annual variation in grain production and yield over 2- to 5-year periods.

Climate, however, is a large and dynamic factor producing some enormous variations in annual crop yield and production from year to year in some identified agricultural sub-regions. It accounts for the major portion of the annual crop yield and production variations for an identified CCI. These large annual variations in global crop production caused by the larger agricultural producing nations greatly affect the availability and prices of the huge amounts of crop exports produced and sold by the U.S. on the international market. The early identifications of these large annual variations in global crop production are in the best interests of the growing global population and its food supply requirements, as well as a cost benefit to the exporting U.S. agricultural economy, and both these interests are prime justifications for this study. This study is a new and flexible general approach to a previous NASA, NOAA, and USDA consortium intensive 5 year unsuccessful effort in the 1970s to solve the same problem.

LACIE, An Unsuccessful Previous NASA Study

This current study uses these new approaches to solve a problem on the variations in grain production, specifically for spring wheat, that has been attempted before by NASA. In the 1970s, a 60 million dollar, 5 year cooperative effort by hundreds of employees in NASA, NOAA, and the USDA was attempted to predict annual variations in grain production. As a rough estimate, the same study could cost in the range of $250-300 million currently. In a single and unique strategic economic intelligence study, the Large Area Crop Inventory Experiment (LACIE), a brute force statistical survey methodology using remotely sensed Landsat reflectance data, was attempted.[4] There was no insight or recognition of the field sizes and the Landsat resolution of the state, collective and private farming structure of the agricultural system being surveyed, and their regional variations, all enormous obstacles to the prediction of Soviet grain production shortfalls. LACIE's justification was based on the large exports of U.S. grain sold to the Soviets in 1972 at then current market prices without previous knowledge of an impending very large Soviet grain production shortfall. The enormous monetary losses to the U.S. from that grain export sale prior to the announced Soviet harvest shortfall prompted the LACIE study.

The resulting LACIE methodology was based on the assumption that a complete survey of all grain-producing areas over the enormous area of the FSU using Landsat reflectance data was the necessary and sufficient essential ingredient for the successful prediction of annual grain shortfalls prior to the grain harvest. The complicated and multi-layered agricultural system targeted was never fully explored in the LACIE development, despite independent efforts by this author to bring these complications to the fore.[5] The brute force approach used in LACIE was so time consuming, expensive, and ineffective that the USDA never implemented the Experiment.

However, the LACIE Cost Benefit Studies costing $2 million in the 1970s are still viable and support and justify the economic value of this study, with its new approach to combined sub-regional climate data sets. It is assumed that this was the only attempt at such a strategic economic intelligence effort by NASA, in a virtual untouched research area with enormous cost benefits to the U.S. and the global agricultural economy and food supply. The CIA, on the other-hand, were experts in country analysis and strategic economic studies, and welcomed any assistance from more scientific organizations conducting satellite surveillance of FSU planted grain regions and studies of the current climatic changes taking place in these regions during the growing season, for real time crop harvest predictions.

Prior to the LACIE period in the early 1970's, Figure 6, in the Appendix, indicates the grain imports required after the major grain crop shortfalls in 1963 and 1965. These grain crop shortfalls and their causes will be discussed in a future paper. The increased FSU grain imports from 1972-1973 and their importance can be inferred from Figure 6.[6] The specific LACIE approach employed a statistical sampling methodology for the entire FSU's grain agricultural planted area using LANDSAT reflectance data and some climate data.[7] The brute force approach can be compared to the drastically different sub-regional change in climate and yield approach of the current study within the framework and methodology of the CCI. This current study considers vulnerable sub-regions over decades to filter out slowly moving near steady-state conditions from large and rapid climate fluctuations and their subsequent large effects on grain crop yields. The CCI methodology also relies on extensive knowledge of the country system under investigation, expected of a strategic economic intelligence study with global applicability.

Conclusion

Due to the unresolved problem of the three different types of farming practices and associated field sizes in the 1970s in the FSU, combined with the restricted resolution of the LANDSAT satellite, the $60 million dollar LACIE Project was unfocussed and, as a result, was unsuccessful and did not produce the desired result. A principal problem with the LACIE approach was the lack of knowledge of the important agricultural grain target areas and their field sizes, the important climate sensitive grain crop regions or sub-countries with varying production and the influence of the three different types of farming practices (Soviet, Collective, and private farming), and their relation to grain crop production and field sizes within the LANDSAT spatial resolution. Regions cultivated under two of the three farming practices had field sizes below the practical resolution of the LANDSAT data, could not be surveyed, and were non-critical grain producers. Also, these regions were not the critical climate sensitive crop country regions with the highly variable production. Simply put, LACIE had not been designed with knowledge of the proper target areas for the experiment on the country with the largest land mass of all other countries on Earth.

An alternative new approach for analysis of agricultural country systems, the CCI approach, emanated from the failed LACIE experience. In this approach, globally important crop-producing regions with historically recognized large production failures each decade from large climatic fluctuations are studied separately, while other crop producing regions without these characteristics are classified as steady state crop producers with minor crop production variations. The methodology separates usually good climate agricultural regions with significant global production, like the United States, with freely available agricultural statistics, from usually fluctuating climatic agricultural regions with significant global production, like grain production region in Central Asia, with poor or unavailable agricultural statistics. With the ongoing development of this methodology, a significantly improved approach to assessing the global annual availability of critical crops in a world with a rapidly increasing population can be realized.

Endnotes

[1] The author has created a division of Global Agriculture into a series of Crop Country Inventories, annual crop production inventories over decades for important crops within a country, for critically climatic sensitive and important crop producing regions in important agricultural producing countries, determined by a variety of criteria.

[2] As previously stated in Endnote 1, the author has created a division of Global Agriculture into a series of Crop Country Inventories. Kazakhstan is one of these critical regions for the globally important agricultural production of the FSU. These important agricultural countries have then been analyzed in terms of steady state and fluctuating regional climatic components that result in large swings in the agricultural yield and production for the specific country or the global agricultural economy as a whole.

[3] Welker, J. E. and Au. A. Y., Long-Term Climatic Variations in the Almati Oblast in Central Asian Kazakhstan: Correlations between National Centers for Environmental Prediction (NCEP) Reanalysis II Results and Oblast Meteorological Station Data from 1949 and the Present.

[4] Although the LACIE Project initially was classified, it became well known and finished in October 1978 with the NASA LACIE Symposium. NASA, National Aeronautics and Space Administration, LACIE, Large Area Crop Inventory Experiment, The LACIE Symposium, Proceedings of Technical Sessions, Vols I&II, JSC-16015. (Houston, Tx.: Lyndon B. Johnson Space Center, 1979).

[5] The LACIE Project was based in the Johnson Space Flight Center in Houston, Texas. However, Dr. William Nordberg, the first Director of the newly created Earth Sciences Directorate at Goddard Space Flight Center in Greenbelt, MD., was the first Landsat Study Scientist and thus was involved in the LACIE Project. A few months before he passed away, Dr. Nordberg was presented with the author's CCI approach to the LACIE Project, authorized the creation of an Earth Science Applications Office, designated the author to head the Office, and fully endorsed the strategic economic analysis of nation states analogous to the CCI approach to the LACIE Project. Because LANDSAT's resolution was poor, the missing link was a climate analyses approach from the GCM data base that was then unreliable and in its infancy in the 1970s. See also statistics on land use in the 1970s in ERS-USDA, Agricultural Statistics of Eastern Europe and the Soviet Union, 1960-80 (Washington, D. C.: U.S. Department of Agriculture, Economic Research Service, ERS-Statistical Bulletin No. 700, 1983), 15. and for the 1980-92 period in Jaclyn Y. Shend, ERS-USDA, Agricultural Statistics of the Former USSR Republics and the Baltic States, (Washington, D. C.: U.S. Department of Agriculture, Economic Research Service, ERS-Statistical Bulletin No. 863, 1993), 10-11 and 20-21.

[6] USSR Agricultural Atlas, (Langley, Va.: Central Intelligence Agency, December, 1974), 5.

[7] NASA, National Aeronautics and Space Administration, LACIE, Large Area Crop Inventory Experiment, The LACIE Symposium, Proceedings of Technical Sessions, Vols I&II, JSC-16015. (Houston, Tx.: Lyndon B. Johnson Space Center, 1979.

Appendix

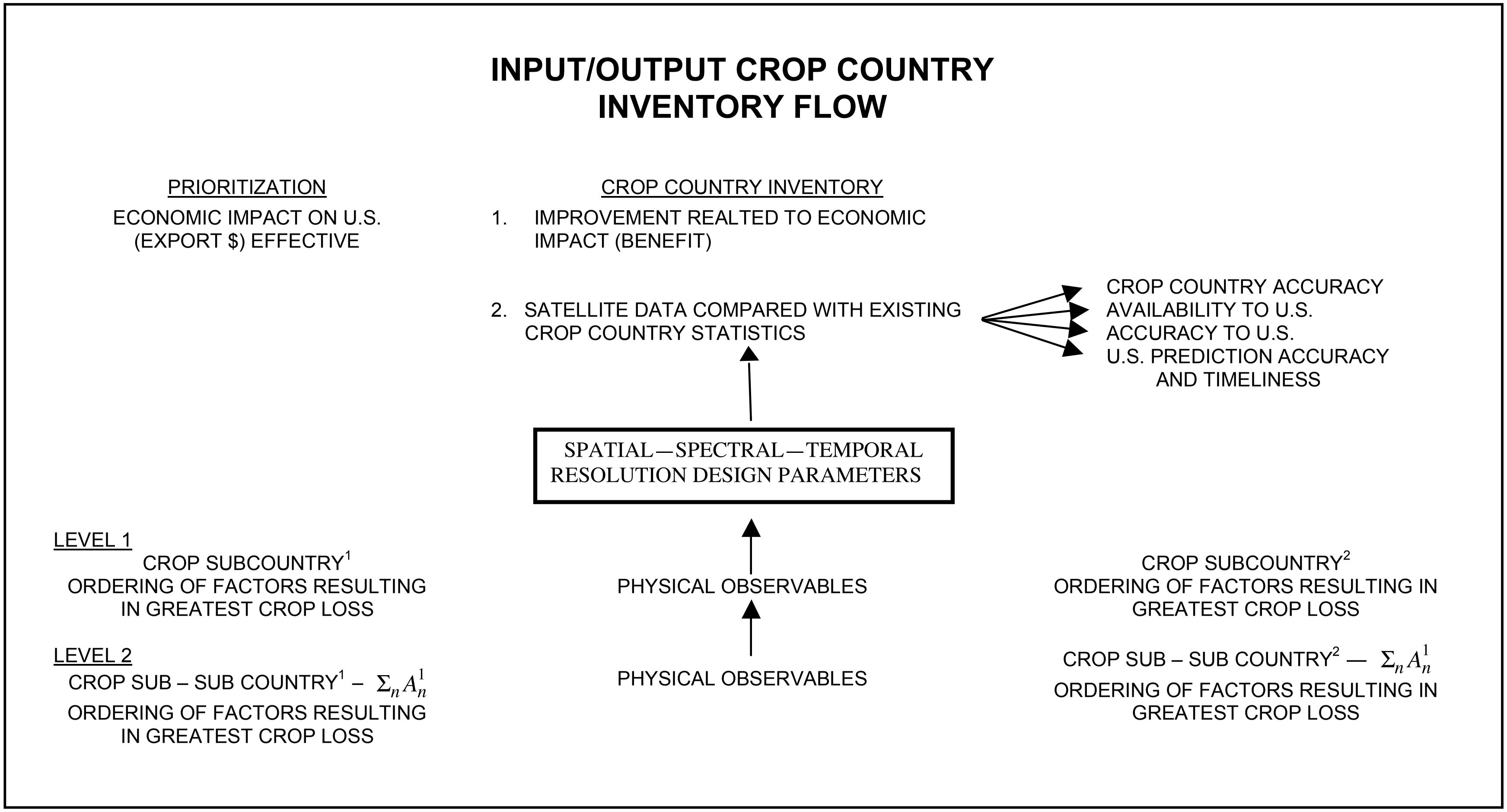

INPUT/OUTPUT CROP COUNTRY INVENTORY FLOW
PRIORITIZATION
ECONOMIC IMPACT ON U.S. (EXPORT $) EFFECTIVE
CROP COUNTRY INVENTORY
1. IMPROVEMENT REALTED TO ECONOMIC IMPACT (BENEFIT)
2. SATELLITE DATA COMPARED WITH EXISTING CROP COUNTRY STATISTICS
CROP COUNTRY ACCURACY
AVAILABILITY TO U.S.
ACCURACY TO U.S.
U.S. PREDICTION ACCURACY AND TIMELINESS
SPATIAL—SPECTRAL—TEMPORAL RESOLUTION DESIGN PARAMETERS
LEVEL 1
CROP SUBCOUNTRY^1
ORDERING OF FACTORS RESULTING IN GREATEST CROP LOSS
LEVEL 2
CROP SUB – SUB COUNTRY^1 – $\Sigma_n A_n^1$
ORDERING OF FACTORS RESULTING IN GREATEST CROP LOSS
PHYSICAL OBSERVABLES
PHYSICAL OBSERVABLES
CROP SUBCOUNTRY^2
ORDERING OF FACTORS RESULTING IN GREATEST CROP LOSS
CROP SUB – SUB COUNTRY^2 — $\Sigma_n A_n^1$
ORDERING OF FACTORS RESULTING IN GREATEST CROP LOSS

FIGURE 1.

PRINCIPAL PRODUCING CROP COUNTRIES

CROP–	**WHEAT**	**RICE**	**CORN**	**BARLEY**
	315.713 MMT	302.2395 MMT	303.502	151.842 MMT
	USSR	PRC	U.S.	USSR
	U.S.	INDIA	PRC	PRC
	PRC	INDONESIA	BRAZIL	CANADA
	INDIA		USSR	FRANCE
	FRANCE		SOUTH AFRICA	U.S.
	OATS	**MILLET**	**RYE**	**POTATOES**
	54.513 MMT	44.146 MMT	29.9315 MMT	286.4195 MMT
	USSR	PRC	USSR	USSR
	U.S.	INDIA	POLAND	POLAND
	CANADA	NIGERIA	FRG	PRC
	POLAND	USSR	GDR	FRG
	FRG			
	SUGAR BEETS	**SOYBEANS**	**(SEEDS) SUNFLOWER**	**COTTON**
	235.2495 MMT	50.7405 MMT	9.5845 MMT	36.169 MMT
	USSR	U.S.	USSR	USSR
	U.S.	PRC	ARGENTINA	U.S.
	FRANCE	BRAZIL	ROUMANIA	PRC
	FRG	USSR	TURKEY	INDIA
	POLAND	INDONESIA		PAKISTAN

FIGURE 2.

WORLD PRODUCTION

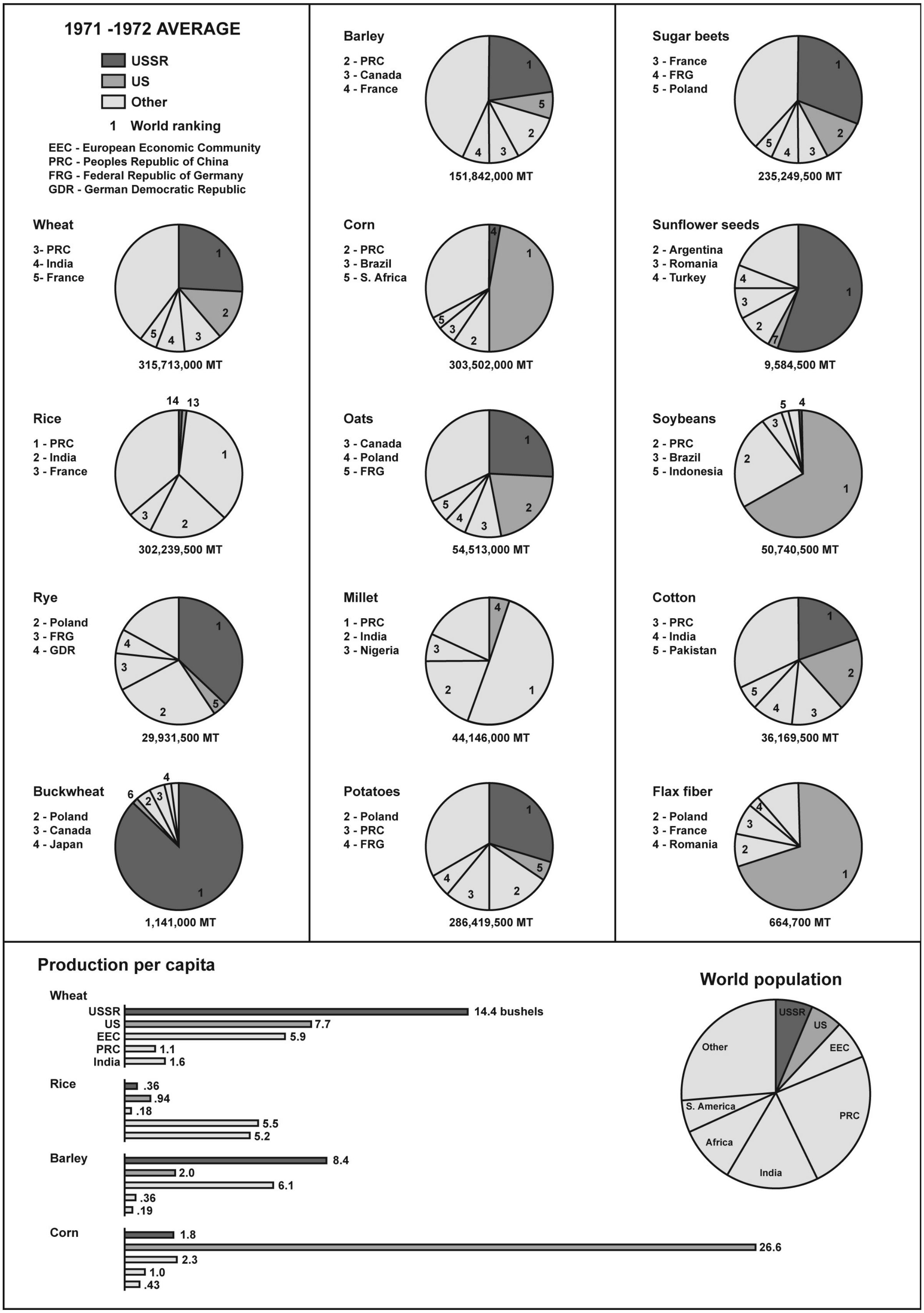


FIGURE 3.

FROM: CROP COUNTRY → CROP SUBCOUNTRY → PHYSICAL OBSERVABLES → SATELLITE DESIGN SPECIFICATION

INITIAL LISTING

CROP COUNTRY PRIORITIZED (U.S. EXPORT $)$_{\text{EFFECTIVE}}$

IMPORT + PRODUCTION = EXPORT + UTILIZATION + STORAGE

FOOD
FEED
SEED
INDUSTRIAL
WASTE

SPECIFIC EXAMPLE

CROP SUBCOUNTRY	CROP SUBCOUNTRY
(1) WINTER WHEAT, UKRAINE	(2) SPRING WHEAT, KAZAK

FIGURE 4.

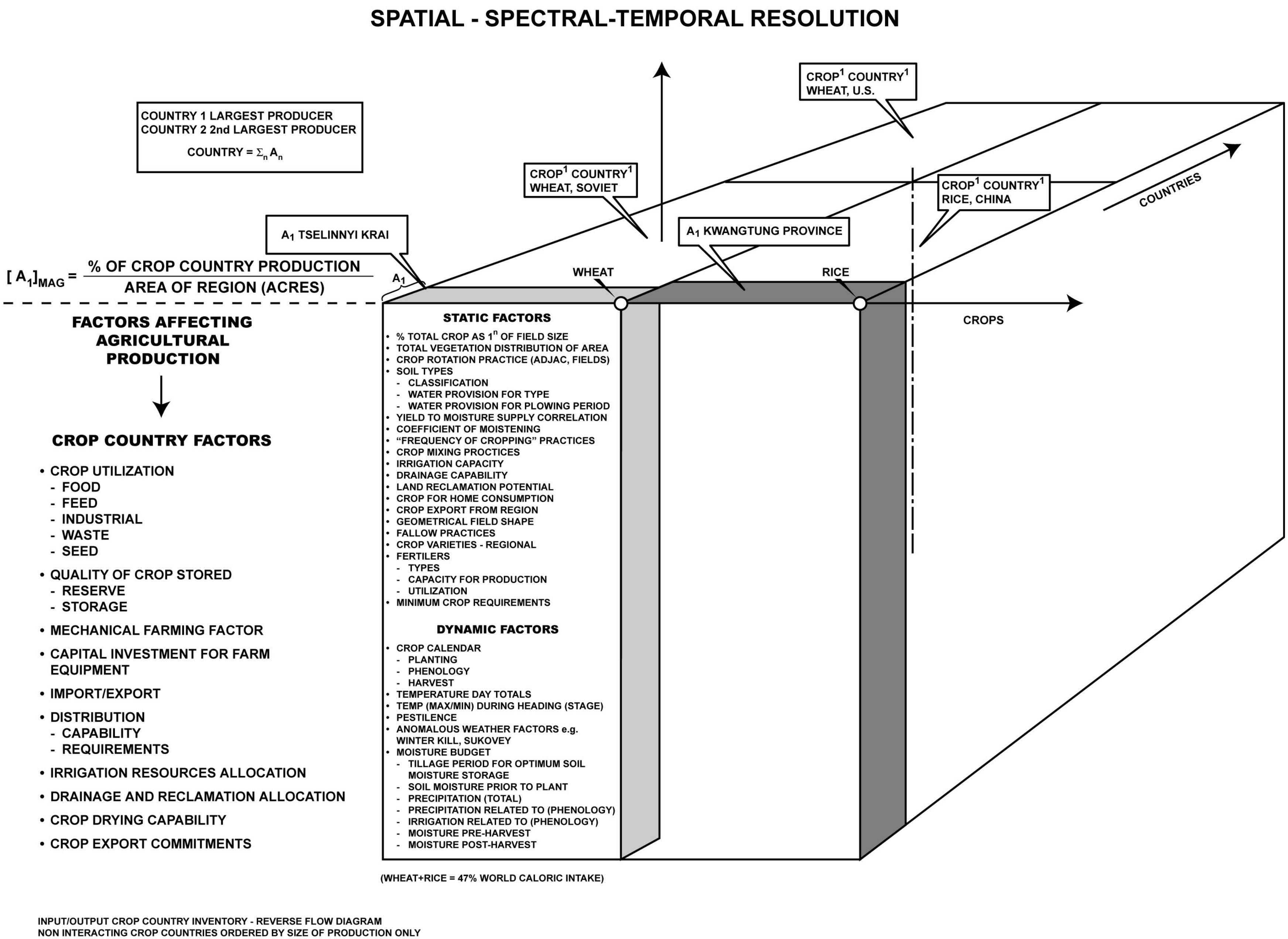
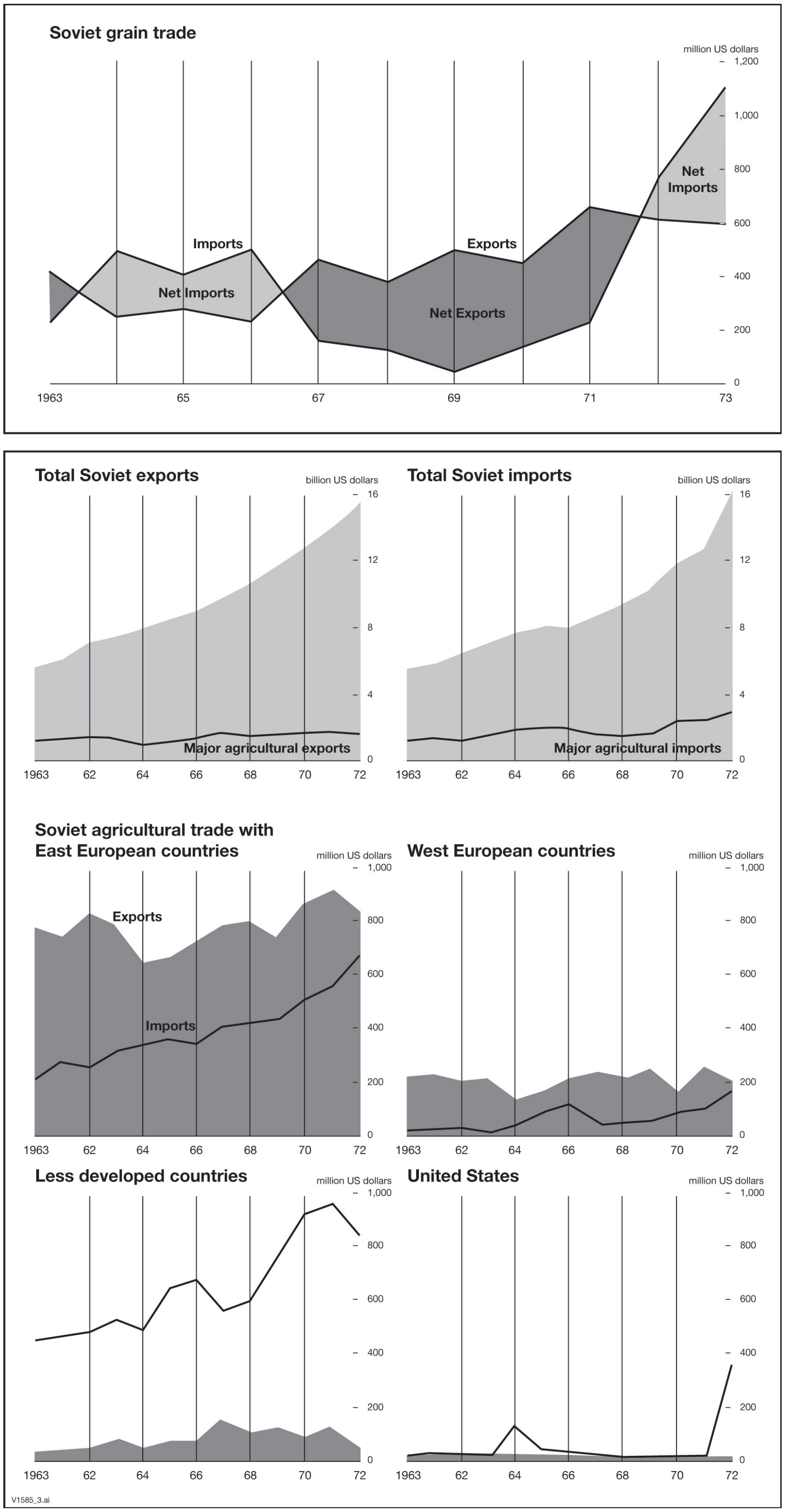

SPATIAL - SPECTRAL-TEMPORAL RESOLUTION
COUNTRY 1 LARGEST PRODUCER
COUNTRY 2 2nd LARGEST PRODUCER
COUNTRY = $\Sigma_n A_n$
CROP[1] COUNTRY[1] WHEAT, U.S.
CROP[1] COUNTRY[1] WHEAT, SOVIET
CROP[1] COUNTRY[1] RICE, CHINA
COUNTRIES
A_1 TSELINNYI KRAI
A_1 KWANGTUNG PROVINCE
$[A_1]_{MAG} = \frac{\text{\% OF CROP COUNTRY PRODUCTION}}{\text{AREA OF REGION (ACRES)}}$
A_1
WHEAT
RICE
CROPS
FACTORS AFFECTING AGRICULTURAL PRODUCTION
CROP COUNTRY FACTORS
• CROP UTILIZATION
- FOOD
- FEED
- INDUSTRIAL
- WASTE
- SEED
• QUALITY OF CROP STORED
- RESERVE
- STORAGE
• MECHANICAL FARMING FACTOR
• CAPITAL INVESTMENT FOR FARM EQUIPMENT
• IMPORT/EXPORT
• DISTRIBUTION
- CAPABILITY
- REQUIREMENTS
• IRRIGATION RESOURCES ALLOCATION
• DRAINAGE AND RECLAMATION ALLOCATION
• CROP DRYING CAPABILITY
• CROP EXPORT COMMITMENTS
STATIC FACTORS
• % TOTAL CROP AS 1^n OF FIELD SIZE
• TOTAL VEGETATION DISTRIBUTION OF AREA
• CROP ROTATION PRACTICE (ADJAC, FIELDS)
• SOIL TYPES
- CLASSIFICATION
- WATER PROVISION FOR TYPE
- WATER PROVISION FOR PLOWING PERIOD
• YIELD TO MOISTURE SUPPLY CORRELATION
• COEFFICIENT OF MOISTENING
• "FREQUENCY OF CROPPING" PRACTICES
• CROP MIXING PROCTICES
• IRRIGATION CAPACITY
• DRAINAGE CAPABILITY
• LAND RECLAMATION POTENTIAL
• CROP FOR HOME CONSUMPTION
• CROP EXPORT FROM REGION
• GEOMETRICAL FIELD SHAPE
• FALLOW PRACTICES
• CROP VARIETIES - REGIONAL
• FERTILERS
- TYPES
- CAPACITY FOR PRODUCTION
- UTILIZATION
• MINIMUM CROP REQUIREMENTS
DYNAMIC FACTORS
• CROP CALENDAR
- PLANTING
- PHENOLOGY
- HARVEST
• TEMPERATURE DAY TOTALS
• TEMP (MAX/MIN) DURING HEADING (STAGE)
• PESTILENCE
• ANOMALOUS WEATHER FACTORS e.g. WINTER KILL, SUKOVEY
• MOISTURE BUDGET
- TILLAGE PERIOD FOR OPTIMUM SOIL MOISTURE STORAGE
- SOIL MOISTURE PRIOR TO PLANT
- PRECIPITATION (TOTAL)
- PRECIPITATION RELATED TO (PHENOLOGY)
- IRRIGATION RELATED TO (PHENOLOGY)
- MOISTURE PRE-HARVEST
- MOISTURE POST-HARVEST
(WHEAT+RICE = 47% WORLD CALORIC INTAKE)
INPUT/OUTPUT CROP COUNTRY INVENTORY - REVERSE FLOW DIAGRAM
NON INTERACTING CROP COUNTRIES ORDERED BY SIZE OF PRODUCTION ONLY

FIGURE 5.



Soviet grain trade
million US dollars
1,200
1,000
800
600
400
200
0
1963
65
67
69
71
73
Imports
Exports
Net Imports
Net Exports
Net
Imports
Total Soviet exports
billion US dollars
16
12
8
4
0
Major agricultural exports
Total Soviet imports
billion US dollars
Major agricultural imports
1963
62
64
66
68
70
72
Soviet agricultural trade with
East European countries
million US dollars
1,000
800
600
400
200
0
Exports
Imports
West European countries
million US dollars
Less developed countries
million US dollars
United States
million US dollars
V1585_3.ai

Figure 6.

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14. ABSTRACT
Ideally, the Crop Country Inventory, CCI, is a methodology for the pre-harvest prediction of large variations in a country's crop production. This is accomplished by monitoring the historical climatic fluctuations, especially during the crop calendar period, in a climate sensitive large crop production region or sub-country, rather than the entire country. The argument can be made that the climatic fluctuations in the climatic sensitive region are responsible for the major annual crop country variations and that the remainder of the country, without major climatic fluctuations for a given year, can be assumed to be a steady-state crop producer. The principal data set that has been used is the Global Climate Mode (GCM) data from the National Center for Environmental Prediction (NCEP), taken over the last half century. As a test of its accuracy, GCM data can and has been correlated with the actual meteorological station data at the station site.

15. SUBJECT TERMS
Crop Country Inventory, CCI, Global Climate Mode, GCM, climate, Large Area Crop Inventory Experiment, LACIE, NASA, NOAA, USDA, Former Soviet Union, Central Asia, Kazakhstan, LANDSAT, crop production

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